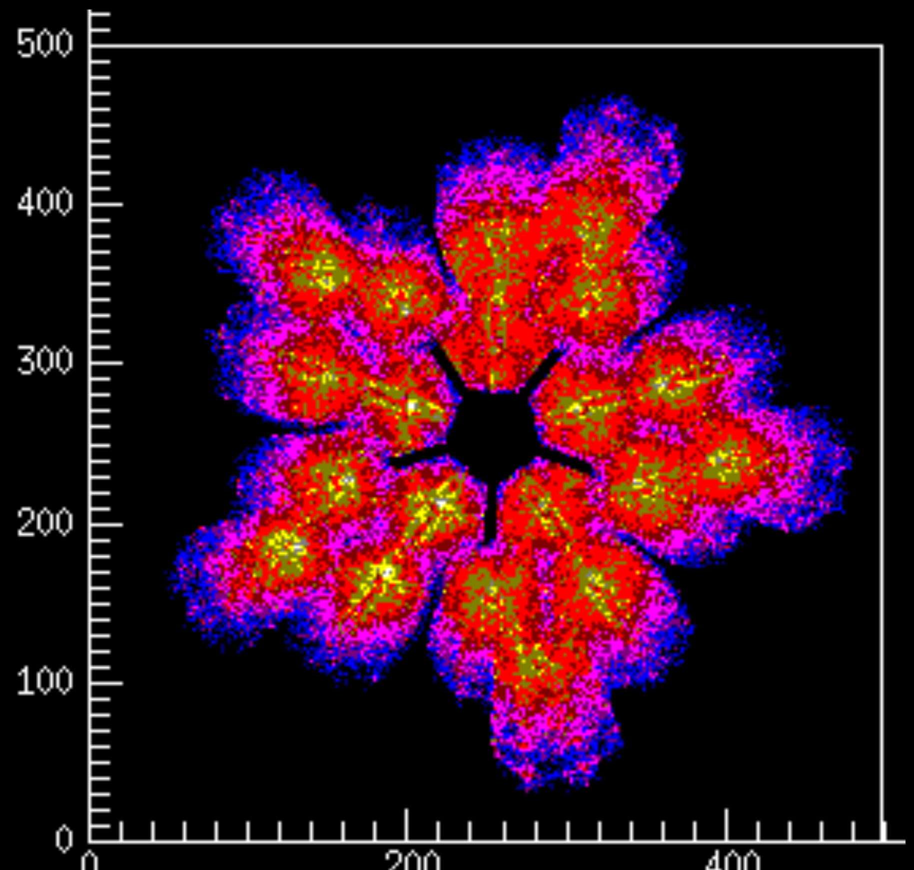
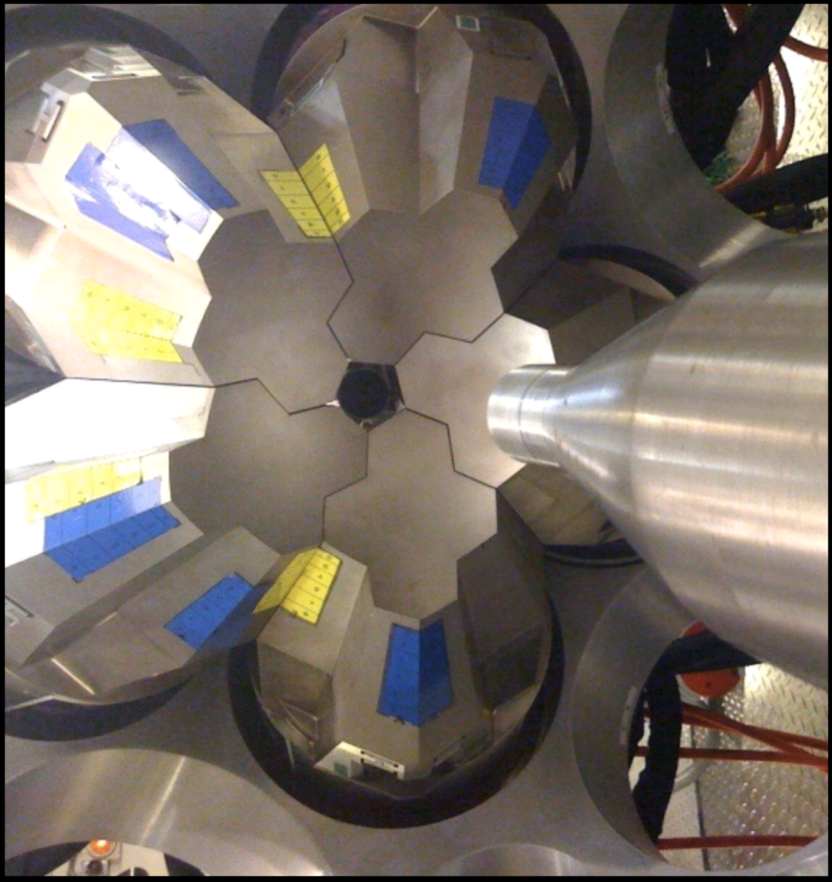
GRETINA's First Year: Status and Results

C. M. Campbell

Lawrence Berkeley National Laboratory



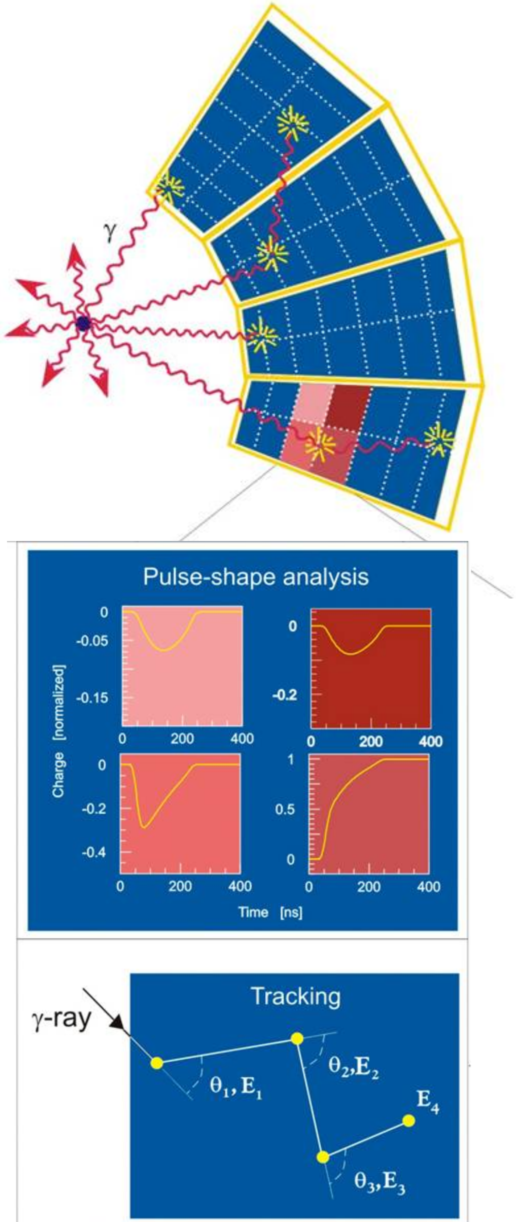


Principle and advantages of γ-ray king

3D position sensitive Ge detector shell

Resolve position and energy of interaction points

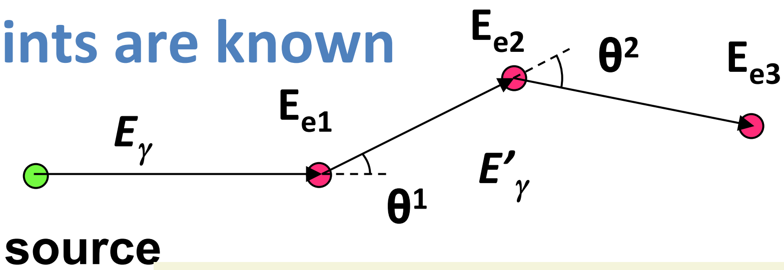
Determine scattering sequence



- Efficiency (50% Ω)
  Proper summing of scattered gamma rays, no solid angle lost to suppressors
- Peak-to-background (60%)
  Reject Compton events
- Position resolution (1-2 mm)
  Position of 1st interaction
- Polarization
  Angular distribution of the 1st scattering
- Counting rate (50 kHz)
  Many segments

Tracking principle

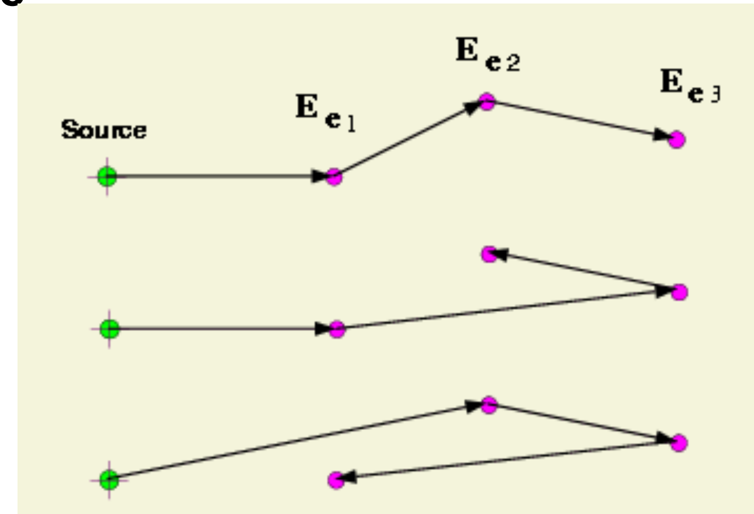
Source location and interaction points are known



1) Assume full energy is deposited

$$\boxed{E_\gamma = E_{e1} + E_{e2} + E_{e3}}$$

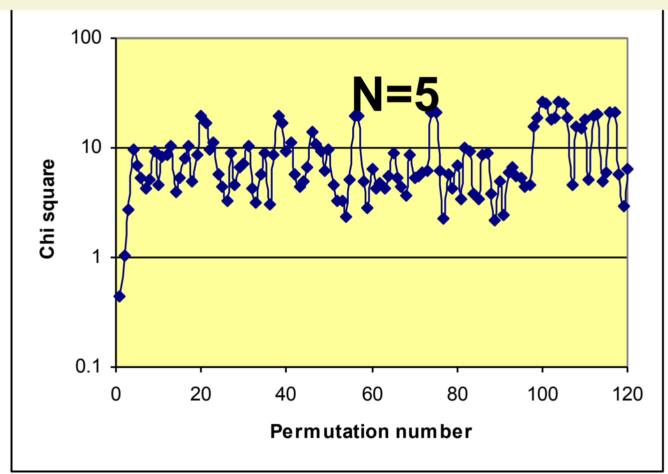
2) Start tracking from the source



For N! possible permutations, check each interaction point for Compton scattering conditions

$$\boxed{\cos\theta_C = 1 + \frac{0.511}{E_\gamma} - \frac{0.511}{E'_\gamma}}$$

$$\boxed{\chi^2 = \frac{1}{N-1}\sum_{i=1}^{N-1}\left(\frac{\theta^i - \theta_C^i}{\sigma_\theta^i}\right)^2}$$



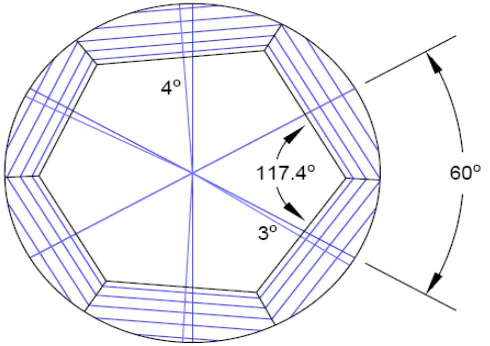
Select the sequence with the minimum $\chi^2 < \chi^2_{max}$

➔ **correct scattering sequence**

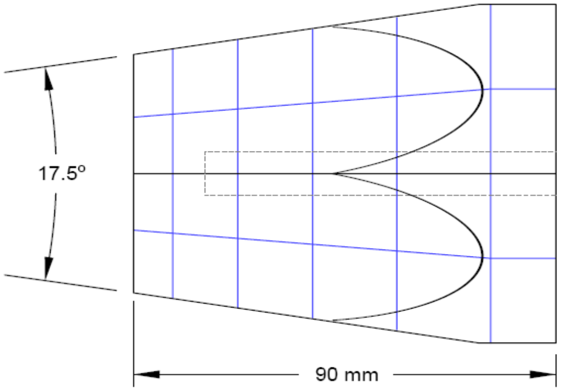
➔ **rejects partial energy event**

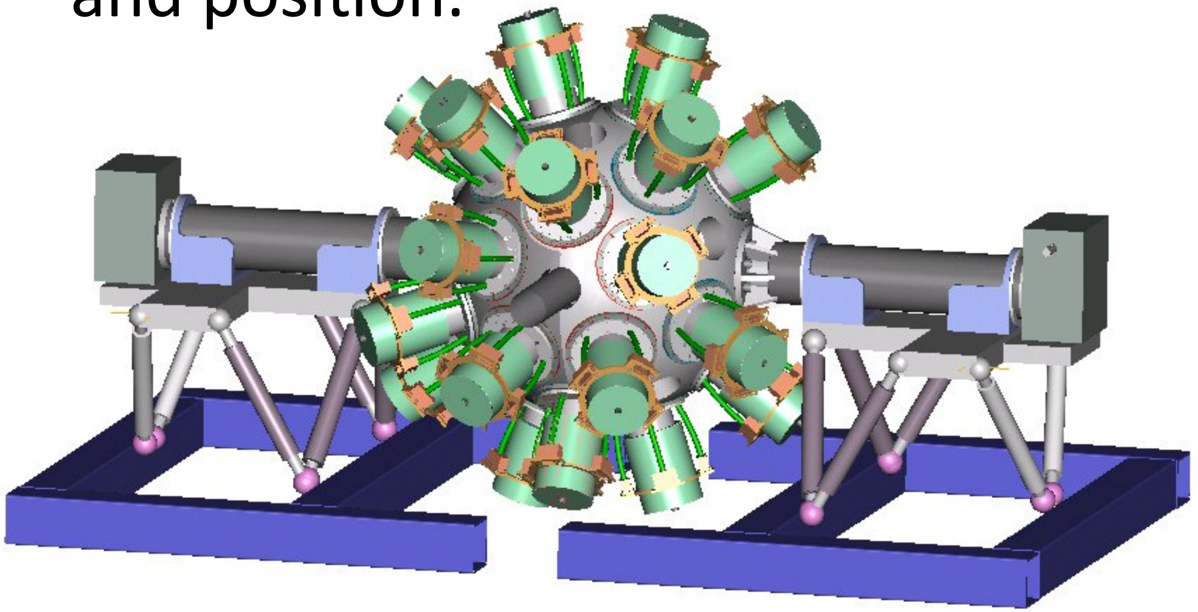
➔ **reject gamma rays with wrong direction**

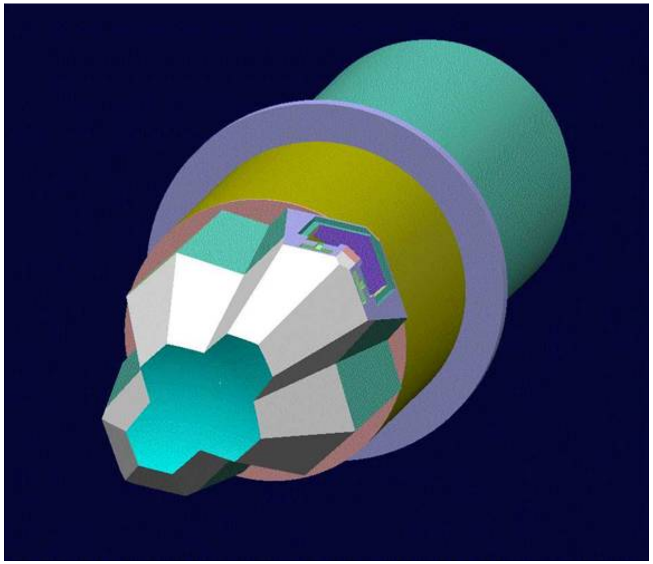
GRETINA Design



- 7 modules of 4 crystals each
- 6 x 6 external segmentation
- Covers ≈ 1π steradian solid angle (to cover 4π will take 30 modules - GRETA).
- Modules can be placed at 58.3º (4), 90º (8), 121º (4), and 148º (5 positions) .
- On-line processing gives γ-ray energy and position.







Gretina DAQ (I)

Each of the 28 crystals has:

- Separate VME backplane and IOC
  - Slow control in EPICS
  - Reads & timesorts digitizer data
  - Passes data to compute cluster
- 4 LBNL Digitizer Modules
  - 10 channels (9 segments + core)
  - 1 Flash ADC / ch, 14bit 100MHz
  - On-board FPGA filters
    - Leading Edge (trigger primitive)
    - Energy (trapezoid)
      - Pole-zero correction
      - Baseline Restoration
- Event data includes:
  - Timestamp
  - Filter data
  - Waveform subset

Gretina DAQ (I)

Trigger system:

- 5 ANL Trigger modules
  - 1 Master + 4 Routers
- Master clock distribution
- Multiple trigger types
  - Multiplicity
  - External (coincidence)
  - Isomer
  - Sum Energy
- Event validation by timestamp broadcast

Gretina DAQ (II): Computing

60 nodes
2 cpu / node
4 core / cpu

Specification:

Processing 20,000 Gamma rays /sec

Data from GRETINA Detectors → *Segment events* (37 segments per detector)

↓

Crystal Event Builder

↓

Crystal events

↓

Signal Decomposition

↓

Interaction points (1-28 crystals)

↓

Data from Auxiliary Detectors → **Global Event Builder** ← **This is where "events" may be defined!**

↓

Global Events

↓

Tracking

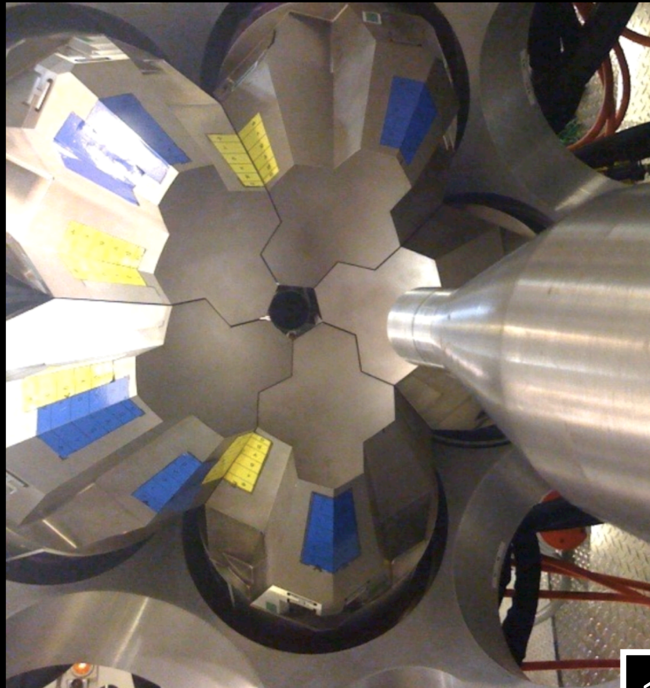
↓

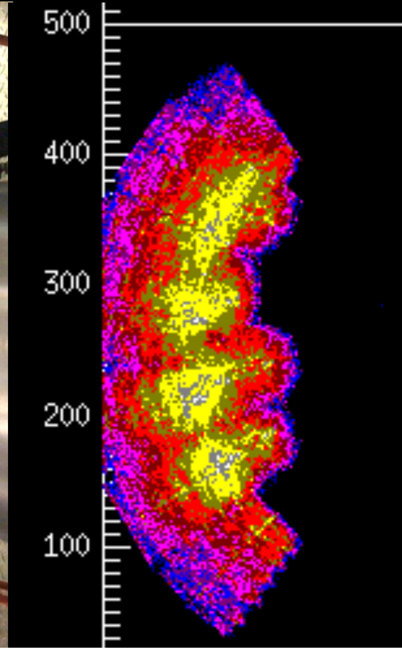
Analysis & Archiving

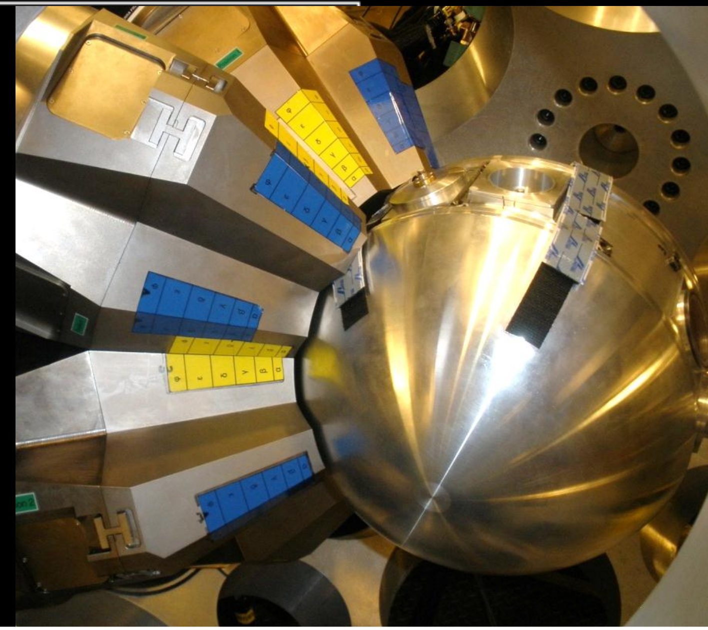
Engineering Runs

Topics: High multiplicity
Isomer decay/trigger
High rates
High energy γ efficiency
Doppler correction
Polarization sensitivity

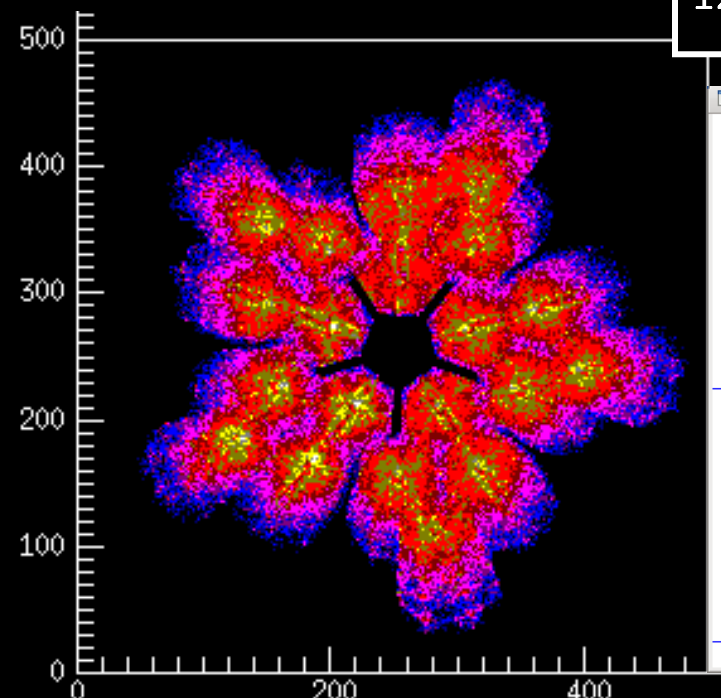
Challenges: Stability
Diagnostics
User interface
Calibration
Computing throughput

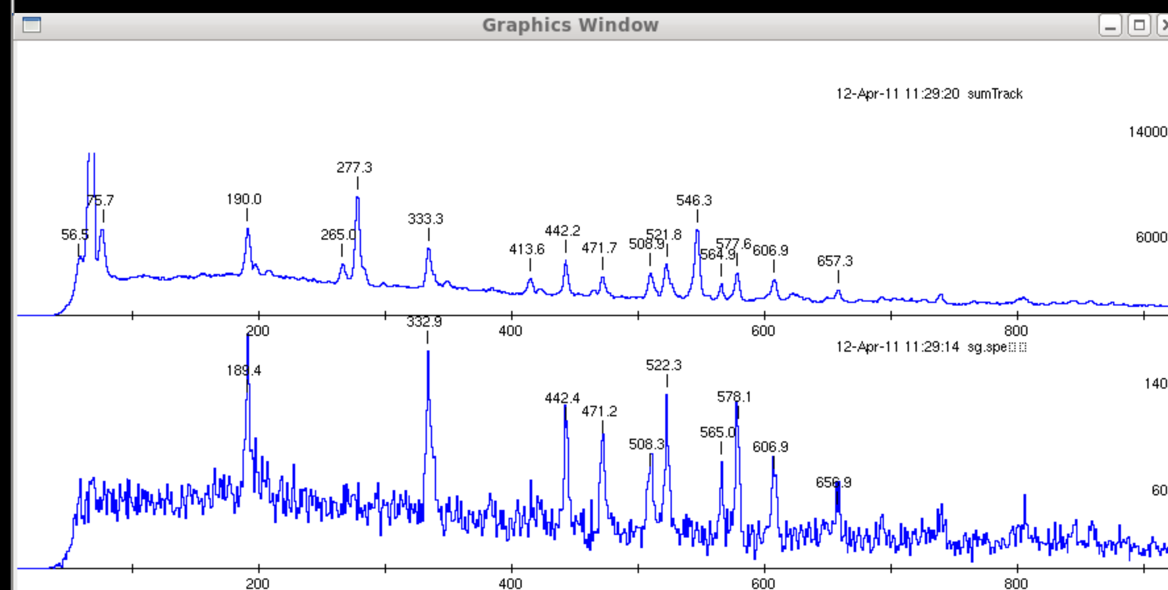






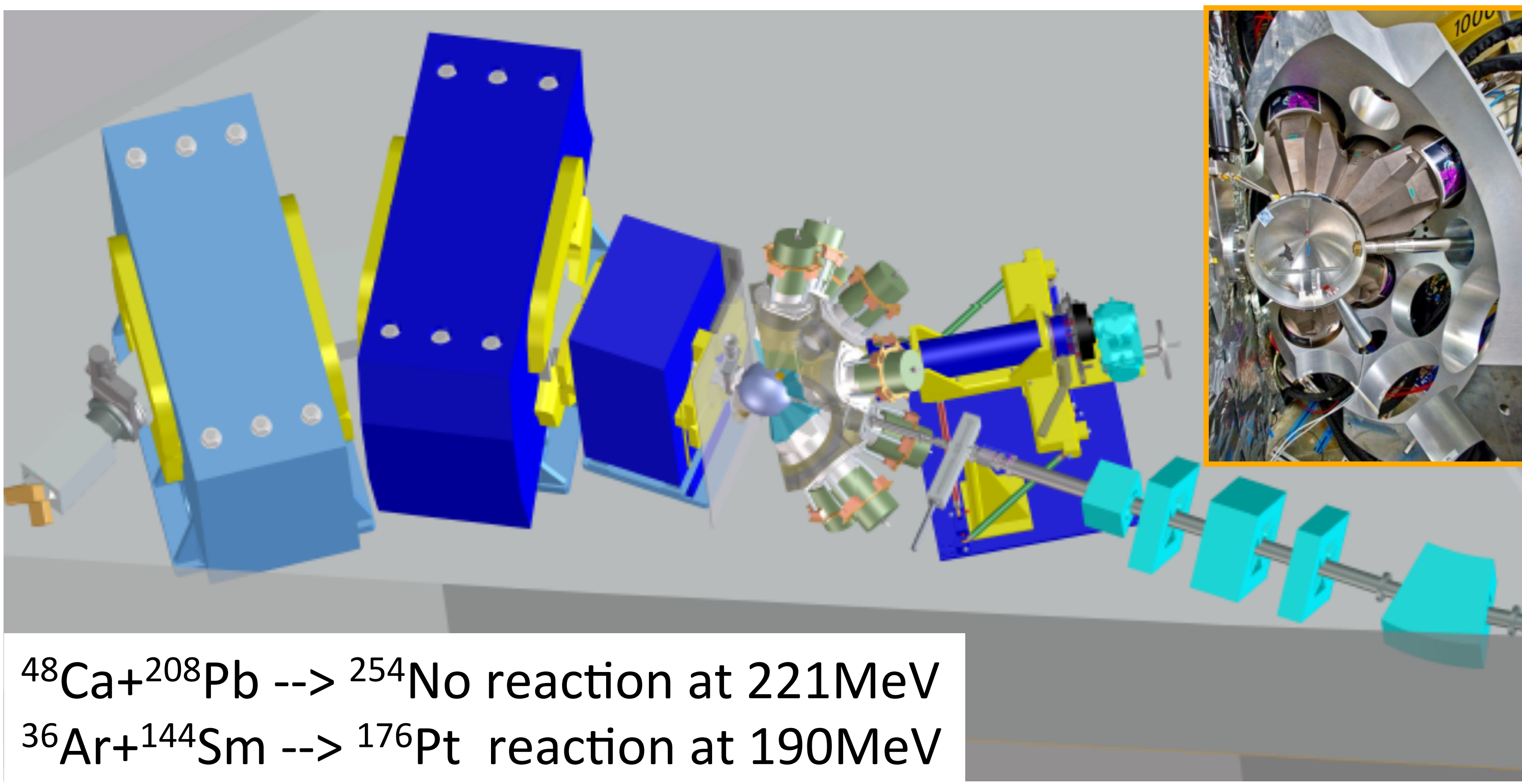
$^{122}Sn(^{40}Ar,4n)^{158}Er$, 170 MeV, v/c = 0.022





Commissioning GRETINA at BGS

- GRETINA set up at BGS target position
- Experiment September 7, 2011 – March 23, 2012

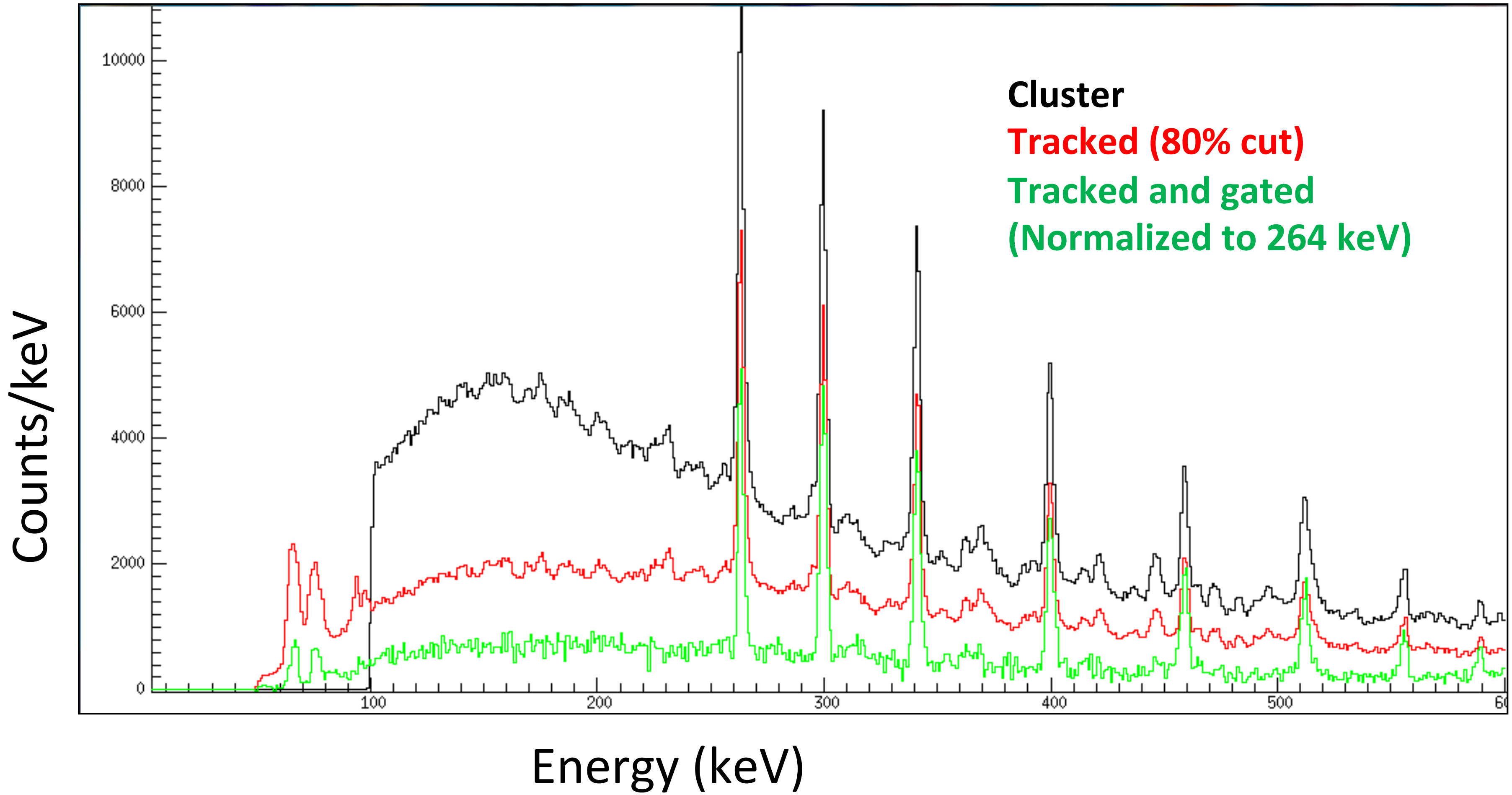


$^{48}Ca + ^{208}Pb$ --> ^{254}No reaction at 221MeV

$^{36}Ar + ^{144}Sm$ --> ^{176}Pt reaction at 190MeV

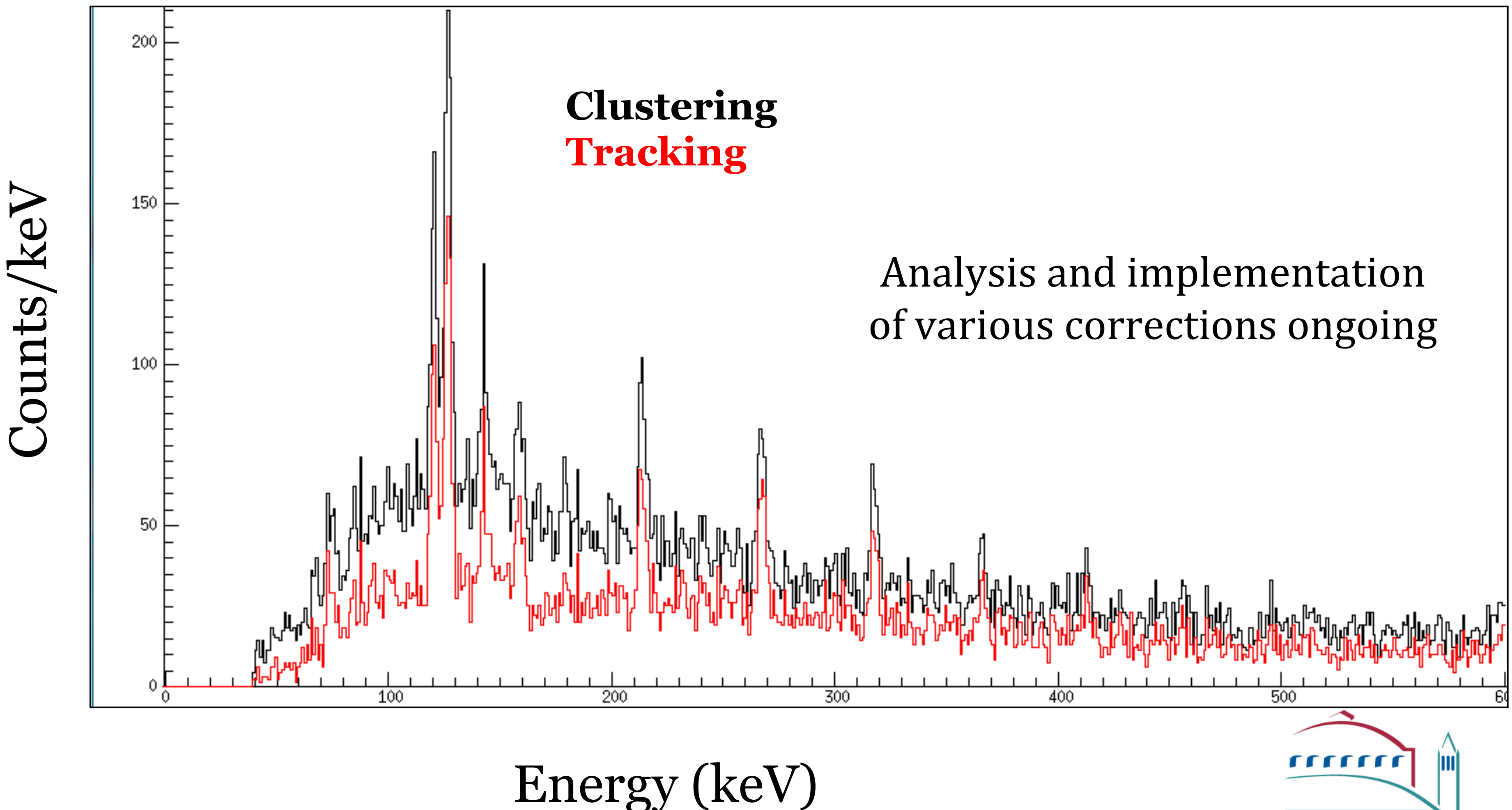
I counted 35 visitors to LBL who took shifts starting in Mid-October.

^{176}Pt


Cluster
Tracked (80% cut)
Tracked and gated
(Normalized to 264 keV)
Counts/keV
Energy (keV)
10000
8000
6000
4000
2000
0
100
200
300
400
500

^{254}No: GRETINA Under Battle Conditions

Over the course of 5 months, we have collected ~ 500,000 recoils of ^{254}No, which represents the world's largest data set .



Challenges and Problems

Known Challenges (Pre-requisites):

- Start-of-Run timestamp synchronization ✓
- Offline data merging ✓

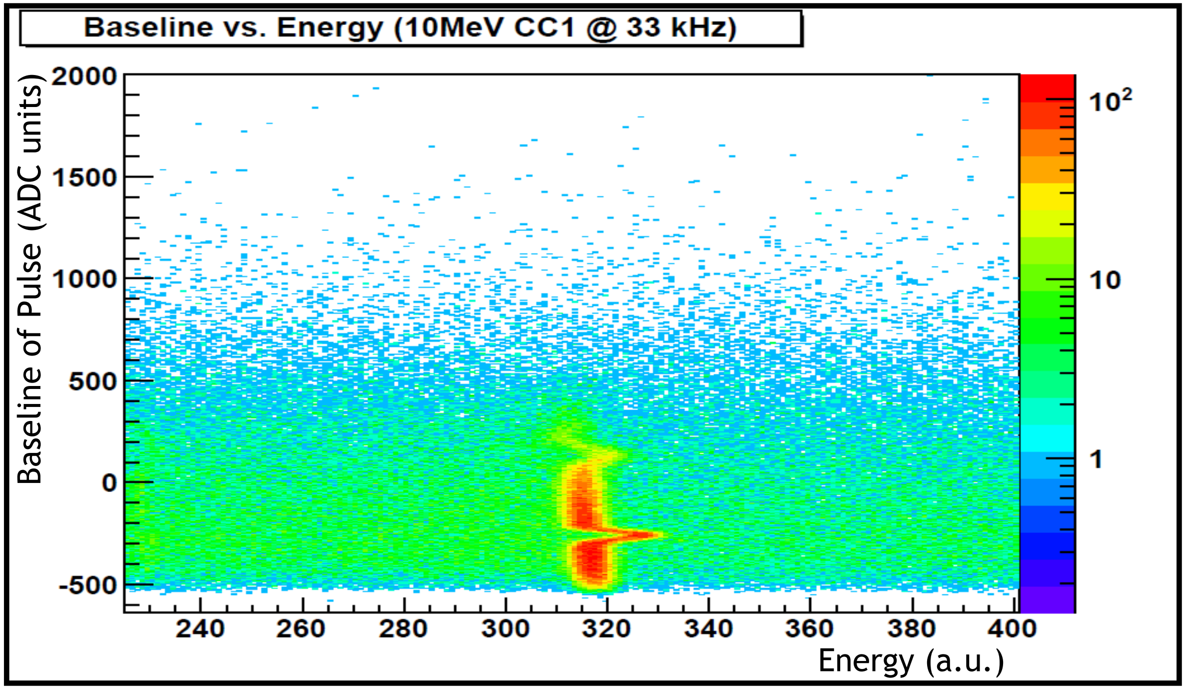
Commissioning at the BGS was first and foremost for **continued debugging and improvement of the array,** with physics results a secondary goal.

Much of the run time was required to fix significant problems.
^{254}No was a good experiment for testing the array and solving issues.

Major problems:

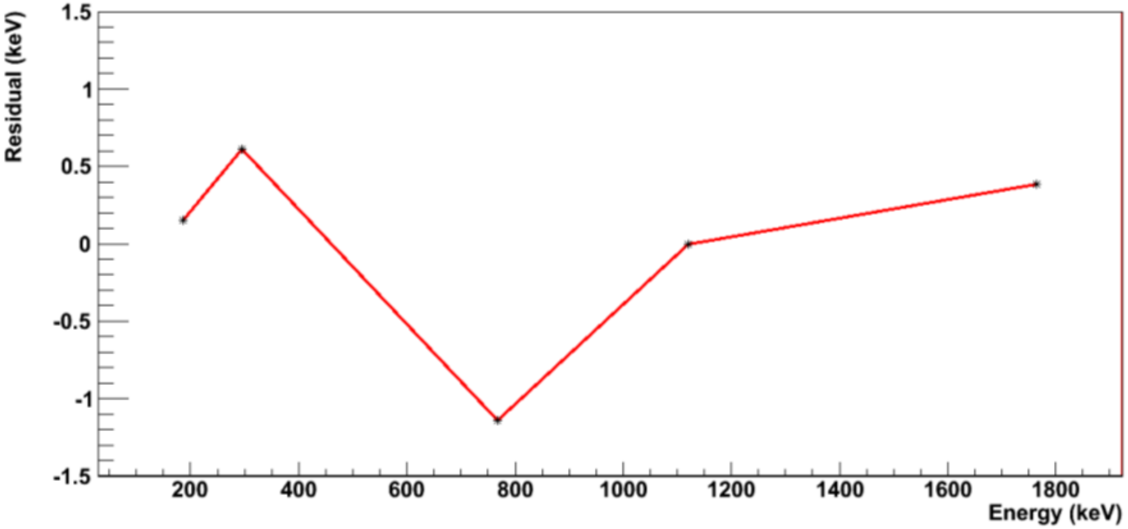
- Non-linearity of the GRETINA ADCs ✓
- Missing energies from the GRETINA digitizers ✓
- Errors maintaining synchronization of electronics ✓
- Pole-zero correction of traces ✓
- Dead time at high crystal rates ✓

Example: ADC Non-Linearity

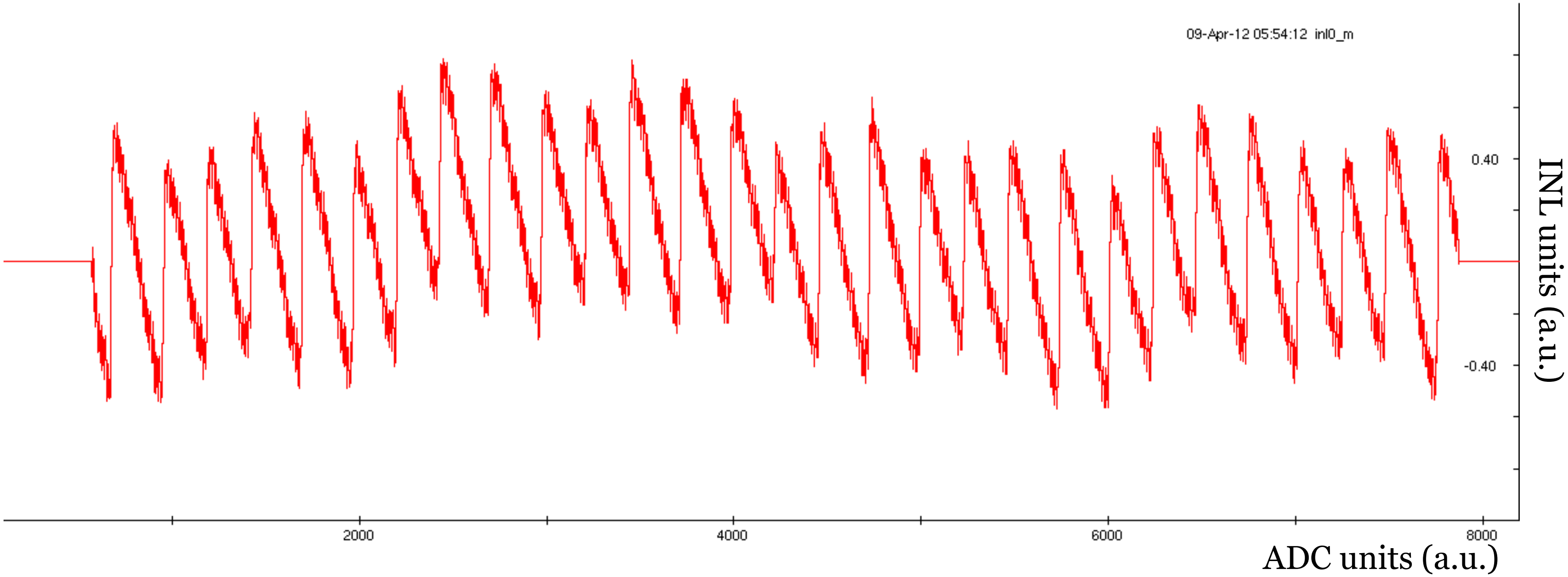


- The ADCs are expected to be linear – a calibration using a straight line should yield small residuals, near zero
- GRETINA digitizers show large deviations from linear behavior

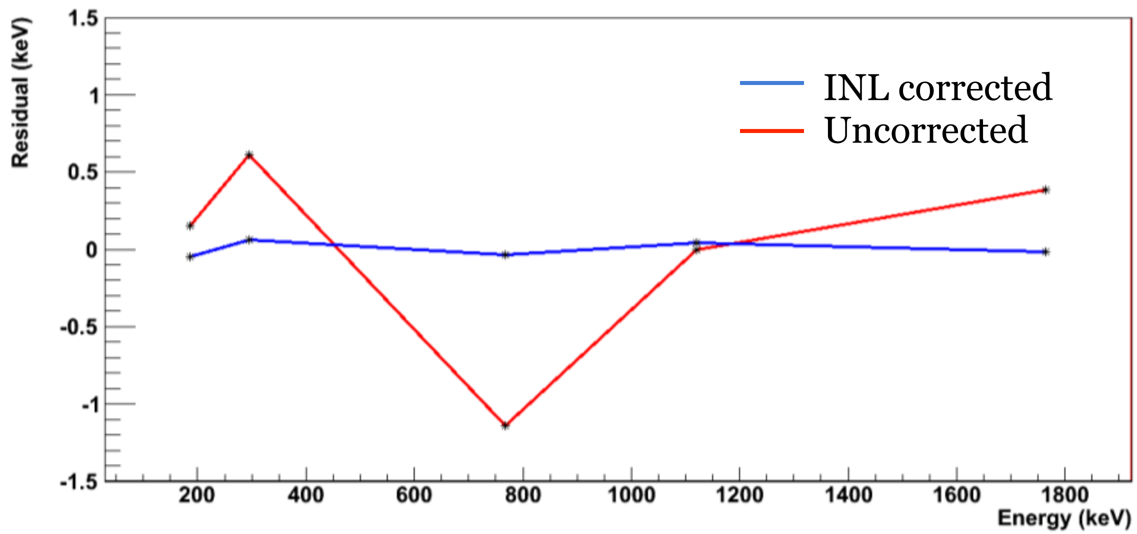
- Non-linearity of the ADC manifests both in calibration residuals and energy vs. baseline plots when running at high (>3kHz) rates



Solution: Detailed Correction



- Directly measure the non-linearity of all 1120 channels, using a pulser
- Correct each gamma-ray, event by event, based on the absolute properties of the ADC

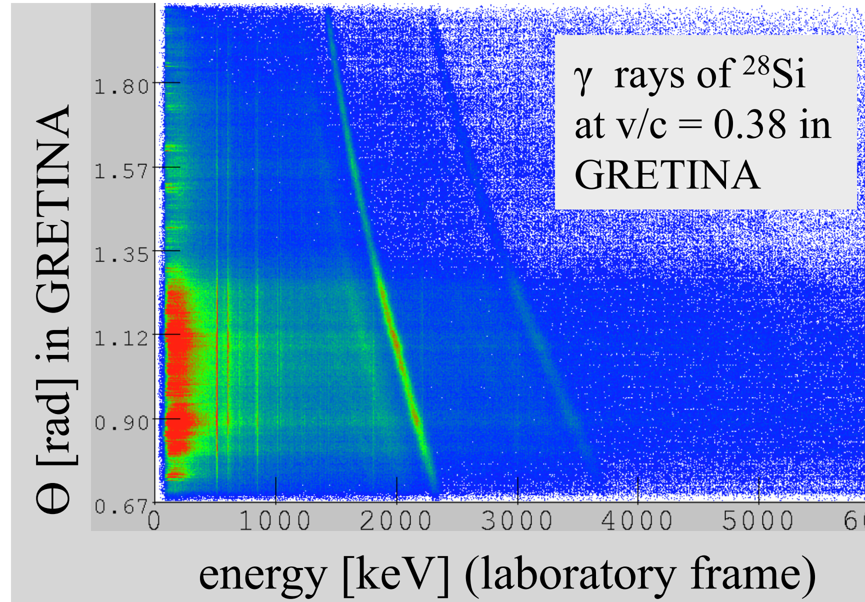


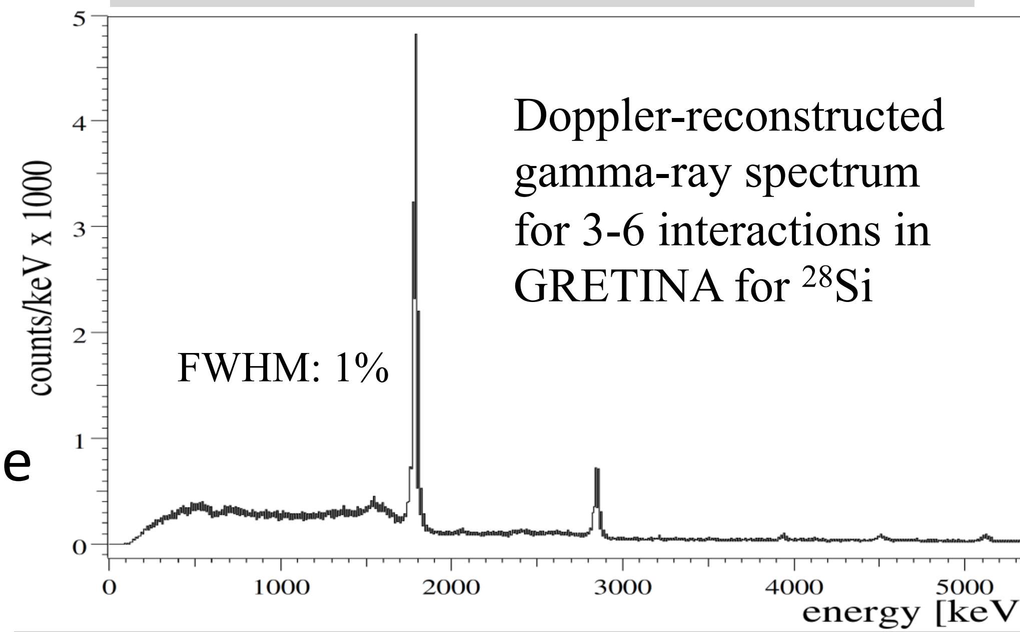
Now: Physics With Fast Beams @ NSCL

With the completion of the commissioning runs, GRETINA was packed and shipped, and was commissioned at NSCL.

Berkeley Lab

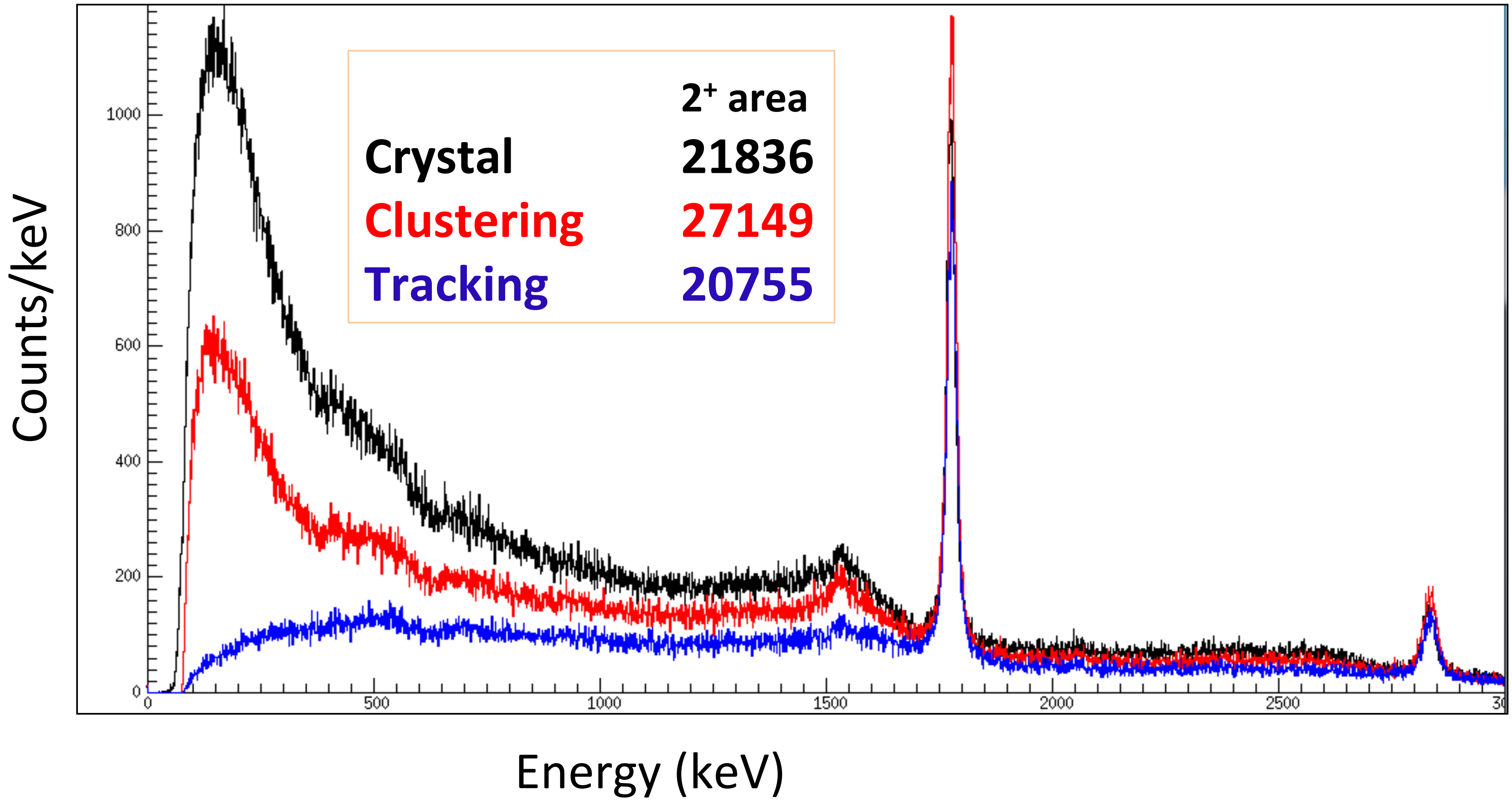
GRETINA experiments with fast beams at NSCL





High statistics commissioning data collected to optimize and benchmark GRETINA performance with fast beams.

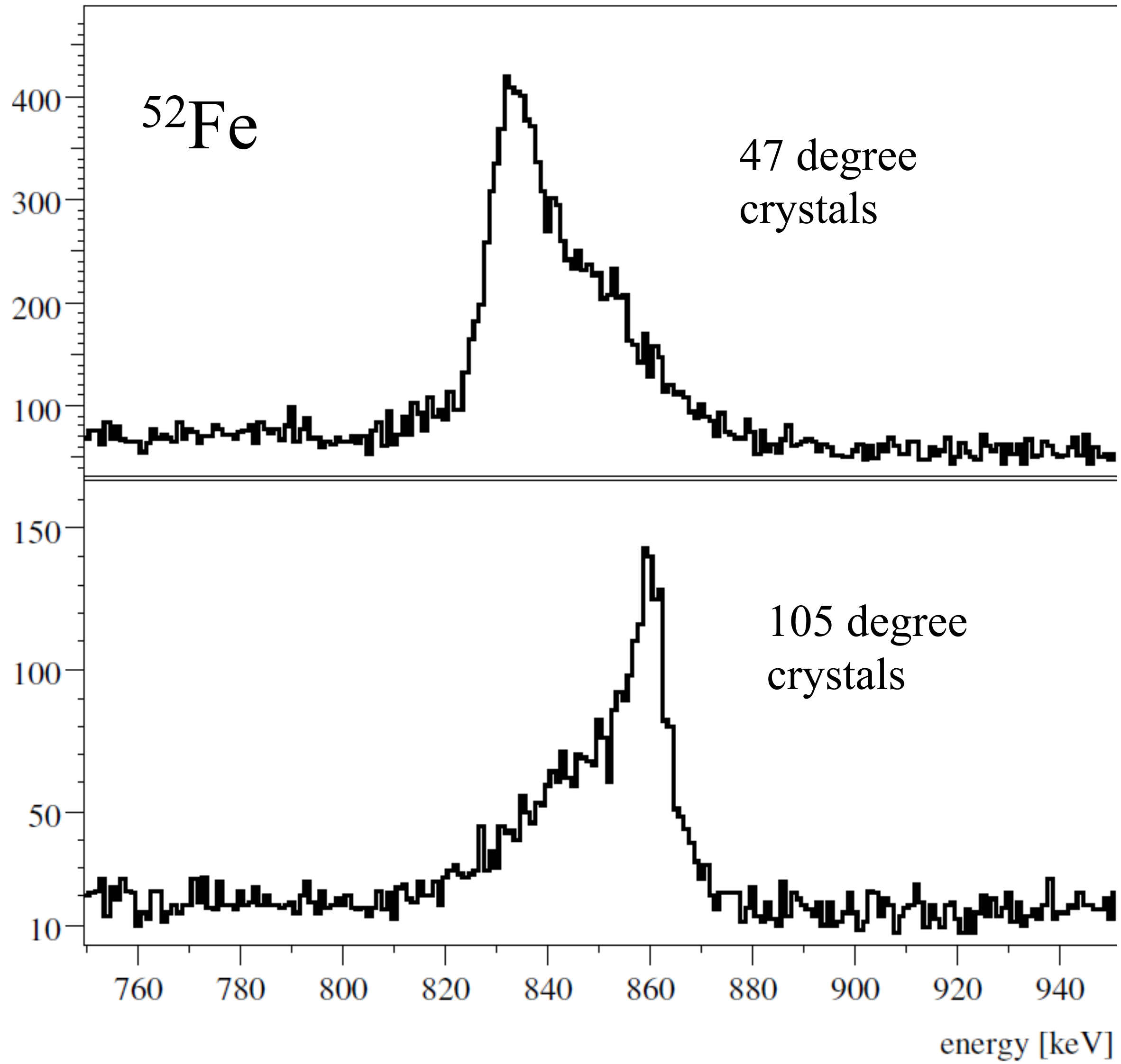
28Si data



Counts/keV
1000
800
600
400
200
0
0
500
1000
1500
2000
2500
2+ area
Crystal 21836
Clustering 27149
Tracking 20755
Energy (keV)

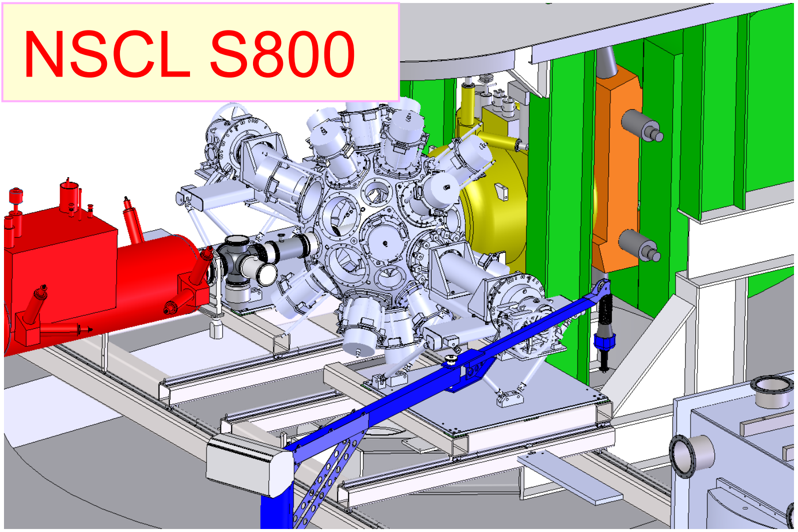
Data from first experiment at NSCL

- ^{52}Fe reaction product
- 849 keV $2^+ \rightarrow 0^+$ transition has two peak components
- Half-life = 7.8(10)ps
- Target ~ 2mm thick
- v/c~0.3 => ~10 ps/mm



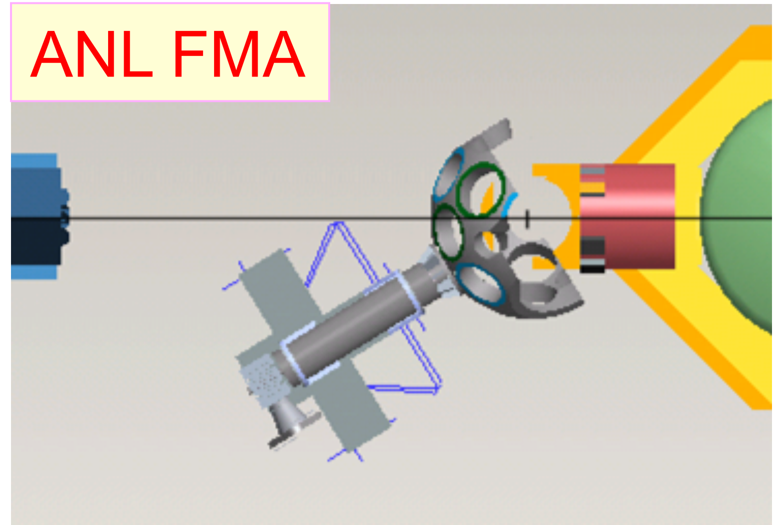
Science campaigns

July 2012



- Single particle properties of exotic nuclei – knock out, transfer reactions.
- Collectivity – Coulomb excitation, lifetime, inelastic scattering.
- 24 experiments approved for a total of 3351 hours.
- First experiment successfully completed. Second experiment just started; reaction data from 6:30am.

Mid-2013



- Structure of Nuclei in ^{100}Sn region.
- Structure of superheavy nuclei.
- Neutron-rich nuclei – CARIBU beam, deep-inelastic reaction, and fission.

Collaborating Institutions

- **Lawrence Berkeley Laboratory**
  - Lead laboratory
- **Argonne National Laboratory**
  - Trigger system
  - Calibration and online monitoring software
  - Tracking program upgrade
- **Michigan State University**
  - Detector testing
- **Oak Ridge National Laboratory**
  - Liquid nitrogen supply system
  - Data processing software
- **Washington University**
  - Target chamber

Acknowledgements

Work force

I-Yang Lee, Sergio Zimmermann, John Anderson, Thorsten Stezeberger, Augusto Macchiavelli, Stefanos Paschalis, Chris Campbell, Heather Crawford, Carl Lionberger, Mario Cromaz, Torben Lauritsen, Steve Virostek, Tim Loew, Dirk Weisshaar, David Radford

Advisory Committee members

Con Beausang**,** Mike Carpenter, Partha Chowdhury, Doug Cline, Augusto Macchiavelli, David Radford (**Chair**), Mark Riley, Demetrios Sarantites, Dirk Weisshaar,

Working Groups and chairs

- Physics — M. A. Riley
- Detector — A. O. Macchiavelli
- Electronics — D. C. Radford
- Software — M. Cromaz
- Auxiliary Detectors — D.G. Sarantites